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We report here the quantitative effects of experimentally increasing the acidity of a mountain stream ecosystem to pH levels frequently found in incident precipitation in the northeastern United States. Our field experiment was designed to test the hypothesis that such acidity of the streamwater would alter the biogeochemistry and the behavior and metabolism of microorganisms, periphyton, macroinvertebrates and fish. We conclude that the biotic structure, metabolism and biogeochemistry of a mountain stream ecosystem underlain by siliceous bedrock were quantitatively altered at pH levels commonly found during snowmelt and in ambient precipitation.

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Ecological effects of experimental acidification on a stream ecosystem

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RONALD J. HALL and GENE E. LIKENS

Section of Ecology and Systematics, Division of Biological Sciences, Cornell University, Ithaca, New York 14850, U.S.A.

Acid precipitation and the resultant increase in acidity in freshwater streams and lakes in sensitive areas of the world are well known.[1-4] Many authors have reported that aquatic organisms at all trophic levels are affected by increased hydrogen ion stress.[5] Most of these studies have been qualitative field surveys or laboratory experiments on the physiological responses of the biota to increased acidity. Little quantitative information, however, is available on the stress of moderately low pH (~4) on the metabolism and biogeochemistry of a natural stream ecosystem.

We report here the quantitative effects of experimentally increasing the acidity of a mountain stream ecosystem to pH levels frequently found in incident precipitation in the northeastern United States. Our field experiment was designed to test the hypothesis that such acidity of the streamwater would alter the biogeochemistry and the behavior and metabolism of microorganisms, periphyton, macroinvertebrates and fish. Procedures and some results of this experiment are presented elsewhere.[6]

Dilute (0.05-1 N) sulfuric acid was manually and continously added to Norris Brook within the Hubbard Brook Experimental Forest, New Hampshire, from 18 April to 20 September 1977. The pH in the reference area varied from 5.9 to 6.4 during the study, whereas a mean in the experimental section was 4.0 (range 3.9 - 4.5).

At low pH, streamwater concentrations of Al, Ca, Mg, K, Mn, Fe and Cd were increased; no significant change was observed for dissolved organic carbon (DOC), Na, NO_3, NH_4, Ni, Pb, Cu or Zn with increased acidity. Emergence of adult mayflies (e.g., *Epeorus, Ephemerella*), some stoneflies (*Malirekus* and *Isoperla*), one caddisfly species (*Dolophilodes*) and some true flies (Orthocladinae and Tanypodinae) decreased at pH 4, but other taxa such as alderflies (*Sialis*) and Stoneflies (*Leuctra* and *Nemoura*) had increased emergence. Significantly greater numbers ($P < .05$, Mann-Whitney U) of immature aquatic invertebrates in the predator, grazer and collector functional groups were found in net collections of drift from the experimental area ($\bar{x} = 1{,}172/100\ m^3/day \pm 404$) relative to the reference section ($\bar{x} = 249/100\ m^3/day \pm 42$ during the first week of continuous acid addition. After the first week, however, total numbers drifting from the experimental area ($\bar{x} = 407/100\ m^3/day \pm 133$) were not significantly different ($P > .10$) than those from the reference area ($\bar{x} = 370/100\ m^3/day \pm 142$) through the end of May.

The total number of emerging aerial adults decreased by 37% in the treatment area (518 individuals) relative to the reference section (832 individuals) during peak emergence in mid-May. Emergence of adults whose aquatic immature stages function as collectors by filtering and temporarily storing fine particulate organic matter (FPOM) in their disgestive tracts decreased by 70% ($P < .05$) in the acidified section. Density of invertebrates in the sediments also decreased by 75% ($P < .05$) in the acidified area compared to those of the reference area in September. Periphyton biomass increased ($P < .01$) at low pH ($\bar{x} = 1.7\ \mu g\ Chl\ a/cm^2 \pm 0.59$) relative to pH 6.4 ($0.30\ \mu g\ Chl\ a/cm^2 \pm 0.16$), but hyphomycete fungal densities decreased. A basidiomycete fungus increased in the experimental area relative to the reference section. Brook trout moved downstream of the acidified area in spring, but some remained in the experimental area during summer and autumn. In addition, brook trout examined during August showed no signs of morphological stress at pH 4 in the acidified area.

During 5 days (18 - 22 April) of pH 4.0 (simulating pH during snowmelt) we estimated the change in magnitude of three transport mechanisms: invertebrates, coarse particulate organic matter (CPOM) and dissolved ions. The chemical composition of the invertebrates and CPOM was measured with a conductive Jarrell-Ash (model 975) Multi-channel Plasma Atom-COMP/Flame Emission spectrophotometer. A mass-balance approach was used in which inputs to the reference area minus outputs from the treatment section (15 m below acid addition point) yielded a net flux of chemical components during the 5-day period. The mean daily net flux of N (11.5 mg ± 4; 43 mg ± 15) and Ca (0.3 mg ± 0.1; 4.4 mg ± 1.6) via the invertebrates and CPOM modes, respectively, was greater ($P < .05$) than net loss of these elements in the water ($P > .10$). The mean daily net flux of Al was significant ($P < .05$) in all three fractions (e.g., invertebrates 0.13 mg ± 0.04; CPOM 35 mg ± 11; dissolved 16,500 mg ± 200) but the greatest absolute amount was lost in the dissolved component. These net fluxes are underestimates of the total loss of chemicals from the stream ecosystem because trout, sculpins and salamanders also moved out of the treatment area but are not included here. Thus, the net loss of N, and possibly P, via the biota during high acidity episodes in spring could be a significant loss from natural stream ecosystems, particularly since low pH values during initial snowmelt periods have been reported for second- and third- as well as first-order streams.[7]

An upstream/downstream fluctuation in pH, influenced by discharge, occurred during the experiment. For example, during high discharge in spring (April and May) pH 4.0 was measured 400 m below the point of acid addition, whereas during low discharge in summer and autumn (mid-June through Sept.) pH 4.5 and 6.1 were measured at 100 m and 400 m, respectively, downstream of the acidification point. The hydrogen ion was neutrialized to a greater degree during low discharge because of increased predominance of groundwater and possibly because of greater contact of streamwater with bottom sediments of the stream.[8] Streamwater chemistry returned to reference concentrations less than 24 hours after termination of acid addition in September.

The intrasystem cycling between the producers/consumers and the abiotic components at low pH depends upon the functional response of different species populations (community) and stream sediment/water ion exchange mechanisms (Figure 1). At lower pH values the rates and timing of physiological function of the biota maybe altered (indicated by the asterisks) without an increase in population mortality.[9] For example, the mayfly *Ephemeralla funeralis* was present in both study reaches during our experiment but individuals were smaller in the acidified area.[10] Presumably more energy from food sources was channeled into regulation of ionic balance and thus less energy was devoted to growth at low pH. When organisms cannot physiologically adjust their ionic balance in response to elevated acidity, death occurs and thus

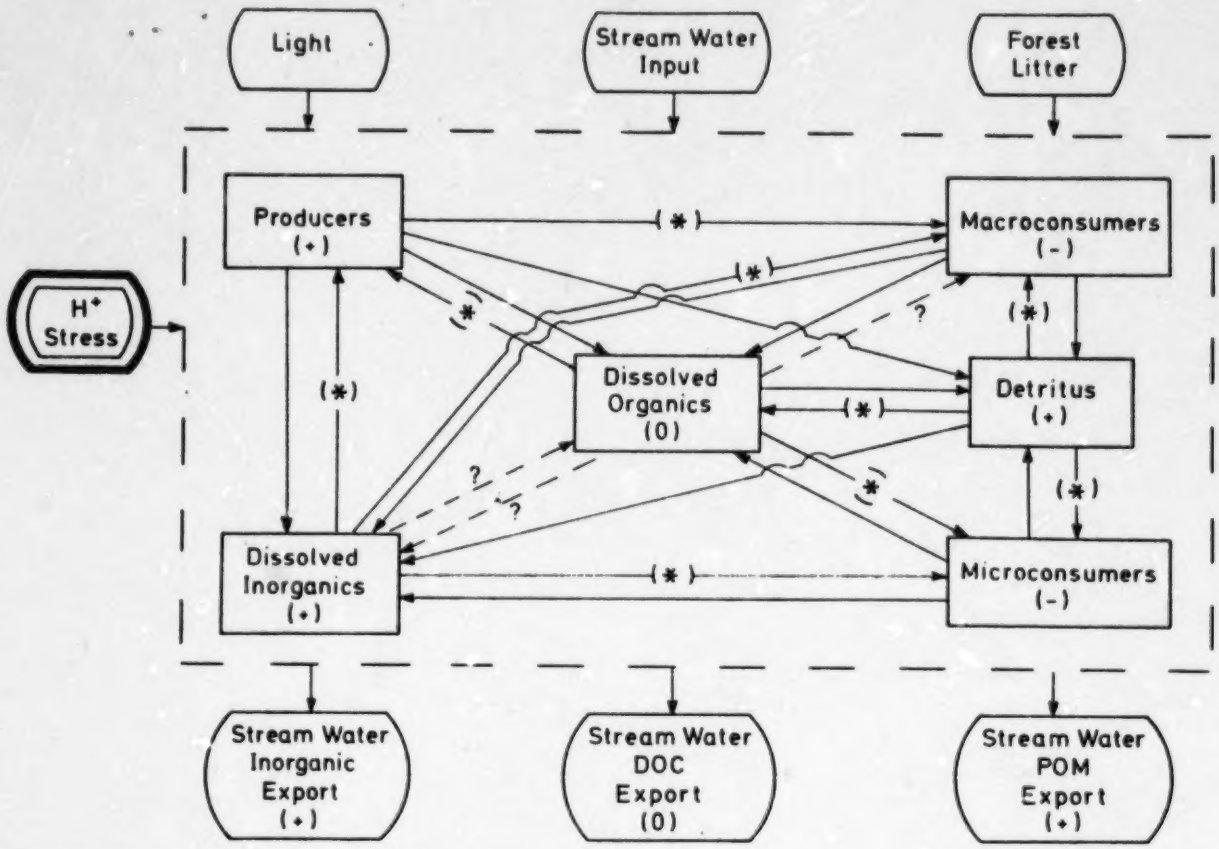

Figure 1. Conceptual model of the effects of hydrogen ion stress (pH 4.0) on biotic and abiotic components of the Norris Brook ecosystem. Boxes represent standing crop; arrows indicate flux of inorganic and organic nutrients. Asterisks represent flows that may be changed (e.g., changes in feeding behavior and adjustments in the physiological responses of organisms to ion exchange mechanisms) before mortality occurs. Plus (+) represents an increase and negative (−) a decrease; zero (0) indicates no change.

densities are reduced (indicated by a negative sign in Figure 1). The process of decay subsequently begins, and nutrients cycle from the biotic (consumer/producer) to the detrital compartment (indicated by a plus sign.)

The net result of intrasystem cycling within the stream ecosystem is the reduction in decomposition and nutrient uptake and an increase in amount of organic matter. However, the relative sizes of the compartments in Figure 1 and the amount of flux that occurs across the ecosystem's boundaries depend upon characteristics of the terrestrial watershed, spatial factors (upstream versus downstream locations[11]), temporal consideratons (e.g., short-term acidic flushes[12] from meltwater versus long-term acidic inputs from precipitation) and intensity of pH stress at any one time.

Overall, increased acidity stressed the biotic and abiotic components of a stream ecosystem as conceptualized in Figure 1. We conclude that the biotic structure, metabolism and biogeochemistry of a mountain stream ecosystem underlain by siliceous bedrock were quantitatively altered at pH levels commonly found during snowmelt and in ambient precipitation.

REFERENCES:

1 R.J. Beamish, W.R. Lockhart, J.C. van Loon, and H.H. Harvey, Ambio, 1975, 4, 98.
2 C.L. Schofield, Ambio, 1976, 5, 228.
3 F.H. Brække, SNSF Project, Research Report 6/76, 1976, 6, 111 pp.
4 G.E. Likens, R.F. Wright, J. Galloway and T. Butler, Sci. Amer., 1979, 8, 39.
5 H. Leivestad, G. Hendrey, I.P. Muniz and E. Snekvik in F.H. Brække, editor, SNSF Project, Research Report 6/76, 1976, 6, p. 87.
6 R.J. Hall, G.E. Likens, S.B. Fiance and G.R. Hendrey, Ecology, 1980, in press.
7 H. Leivestad and I.P. Muniz, Nature, 1976, 259, 391.
8 R.J. Hall and G.E. Likens, 1980, in preparation.
9 R.V. O'Neill, B.S. Ausmus, D.R. Jackson, R.I. van Hook, P. van Vores, C. Washburne and H.P. Watson, Water, Air and Soil Pollut., 1977, 8, 271.
10 S.B. Fiance, Oikos, 1978, 31, 132.
11 N. Johnson, Science, 1979, 204, 497.
12 M. Johannessen and A. Henriksen, Water Resour. Res., 1978, 14, 615.